

SPICA

Space Infrared Telescope for Cosmology & Astrophysics (formerly know as HII/L2)



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ISAS/JAXA

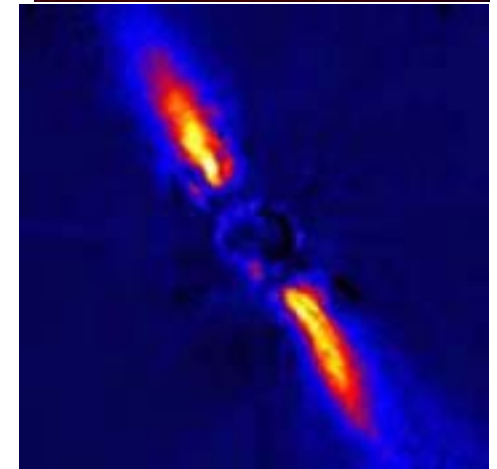
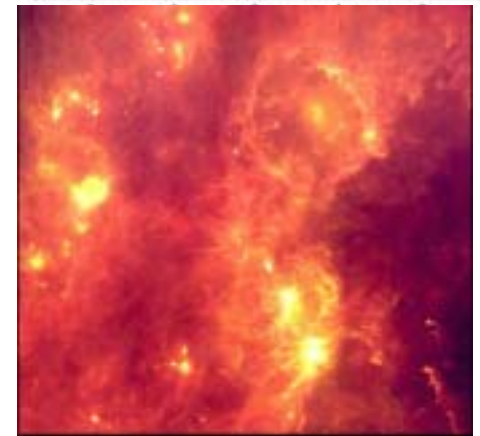
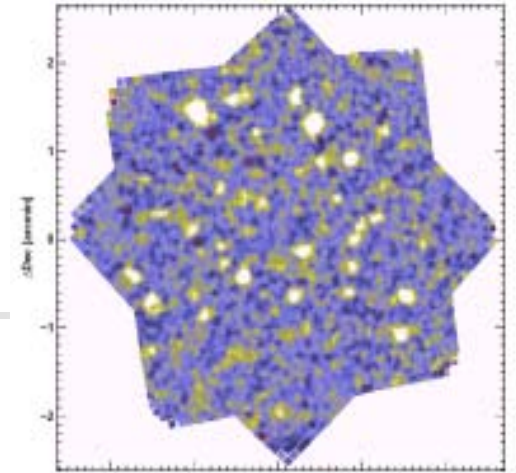


(Institute of Space and Astronautical Science)

Scientific Objectives

Evolution of Universe

- Birth and Evolution of Galaxies
 - Star formation rate & AGN formation
 - Obscured Objects
- Star formation and interstellar chemistry
 - Fine Structure lines, PAH, ...
 - Astro-mineralogy
- Circumstellar Disks & Planetary formation
 - Possible Direct Detection of Exoplanets ?



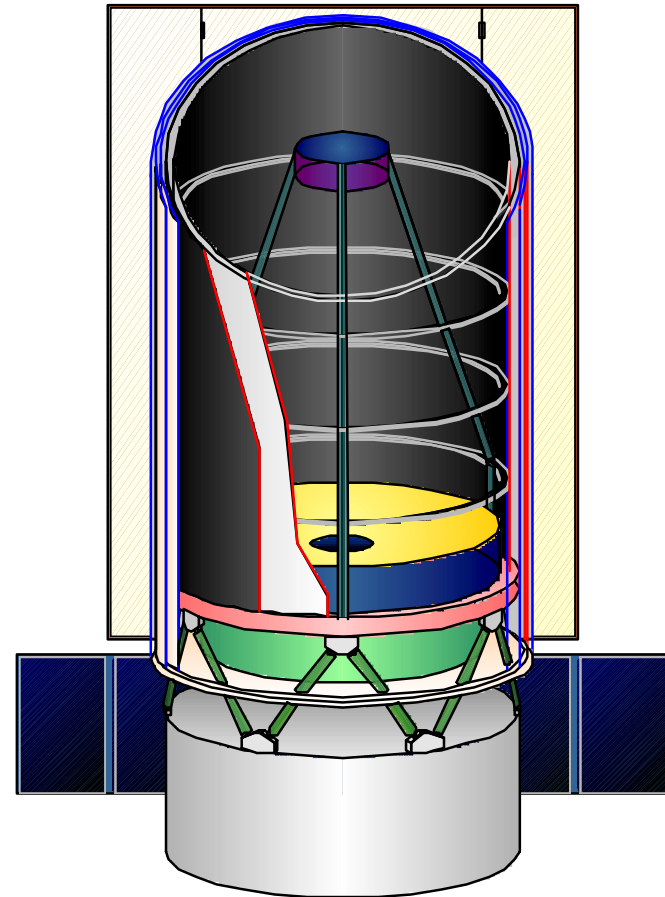


From Spitzer to Herschel & Beyond

- Previous Heritage
 - IRAS, COBE, ISO, IRTS, ...
- SPITZER now and ASTRO-F soon
 - Limited Spatial Resolution and Sensitivity
 - ASTRO-F All Sky Survey needs follow-ups
- Next Step
 - Higher resolution, better sensitivity
 - Cooled, Large Telescope !

Outline of SPICA

- Scientific Objectives
 - To reveal history of universe through Infrared Observations
- Instrument
 - Telescope: 3.5m, 4.5 K
 - Core λ : 5-200 μ m
 - Orbit: Sun-Earth L2 Halo
 - Warm Launch, Cooling in Orbit
 - No Cryogen
- Launch: Early 2010s





Presentations related to SPICA

■ Oral Presentations

- “SPICA Mission”, T. Nakagawa
- “Cryogenics for SPICA”, T. Matsumoto
- “BG Limited FIR Spectroscopy”, M. Bradford
- “H₂ and HD emission from the 1st generation of Stars”, R. Nishi

■ Poster Presentations

- “Telescope system for SPICA”, T. Onaka
- “Cryocoolers for SPICA”, Sugita
- “FIR Detection Limits and Sky Confusion”, W. S. Jeong, S. Pak
- “Disks and Extrasolar Planets”, M. Tamura



Heritage from Previous IR Missions in Japan

IRTS on SFU

- 1st Japanese Space Mission for IR Astronomy
 - Launched in Mar. 1995 onboard SFU
- 15 cm cooled telescope
- Mainly for Diffuse Emission
 - 2-800 μm



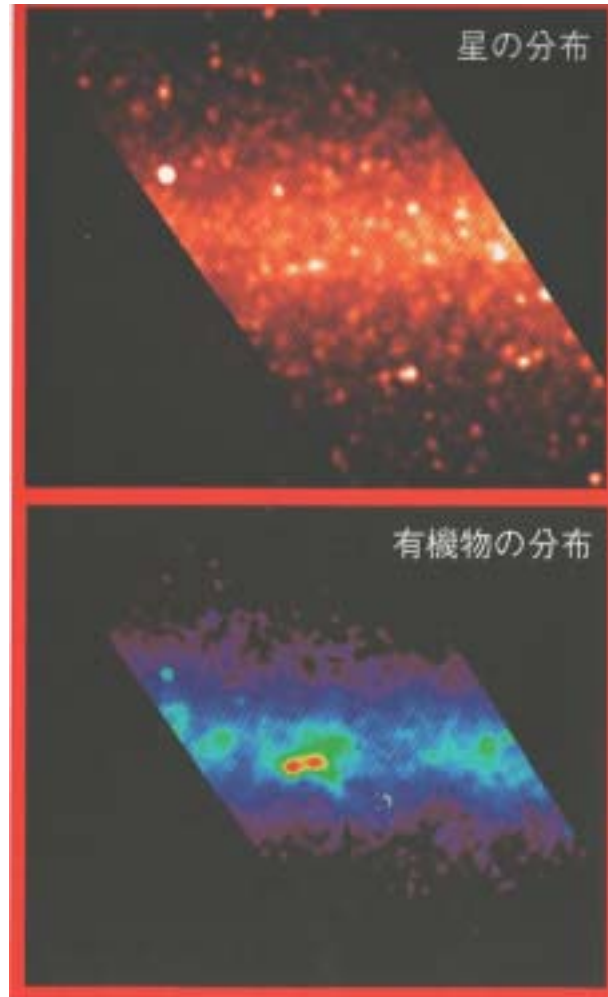
IRTS Heritage

■ Scientific Heritage

- Interstellar Chemistry
- Infrared Background
- Systematic Study of Late-type Stars

■ Technical Heritage

- Superfluid He in Space
- ^3He Refrigerator (0.3 K)

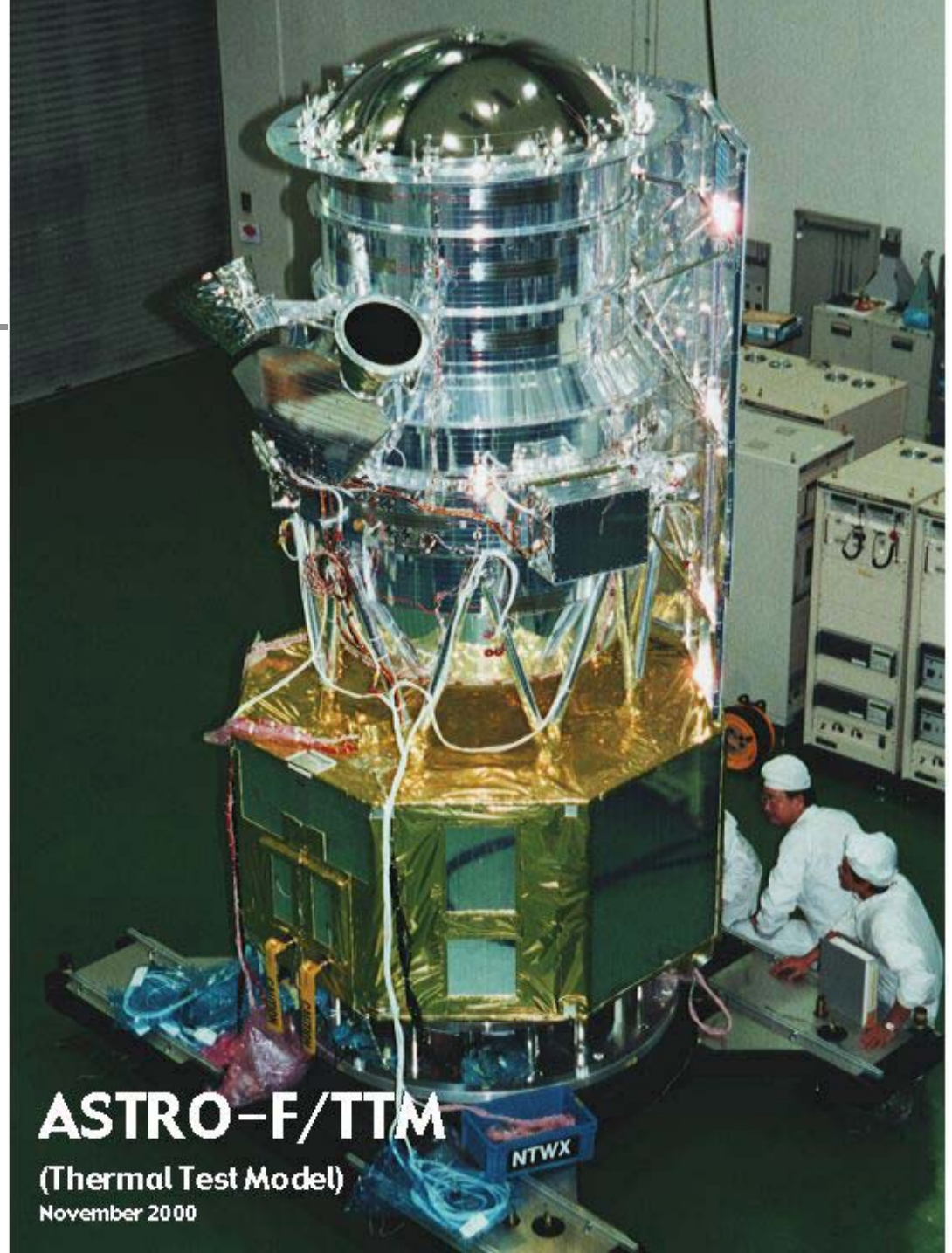


3.3 micron
Continuum
(Stars)

3.3 micron
Feature
(Polycyclic
Aromatic
Hydrocarbon)

ASTRO-F

- 68.5cm Telescope
- NIR-FIR
 - All-sky Survey in FIR
 - Pointing Obs. In NIR-FIR
- Launch: 2005



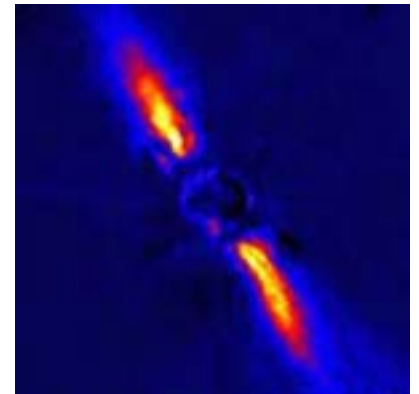
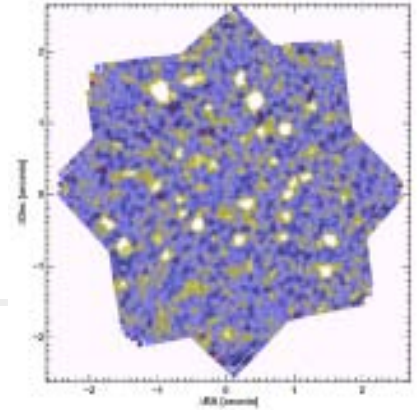
Heritage of ASTRO-F

- Expected Scientific Heritage
 - FIR All Sky Survey
 - Large-Area NIR-MIR Survey
 - Imaging Spectroscopy
- Technical Heritage
 - Mechanical Cryocooler
 - Light-weight Telescope
 - Large-Format Detectors



Strategy

- Scientific Strategy
 - Survey Observations
 - IRTS, ASTRO-F
 - Detailed Observations
 - SPICA
- Technical Strategy
 - Step by step

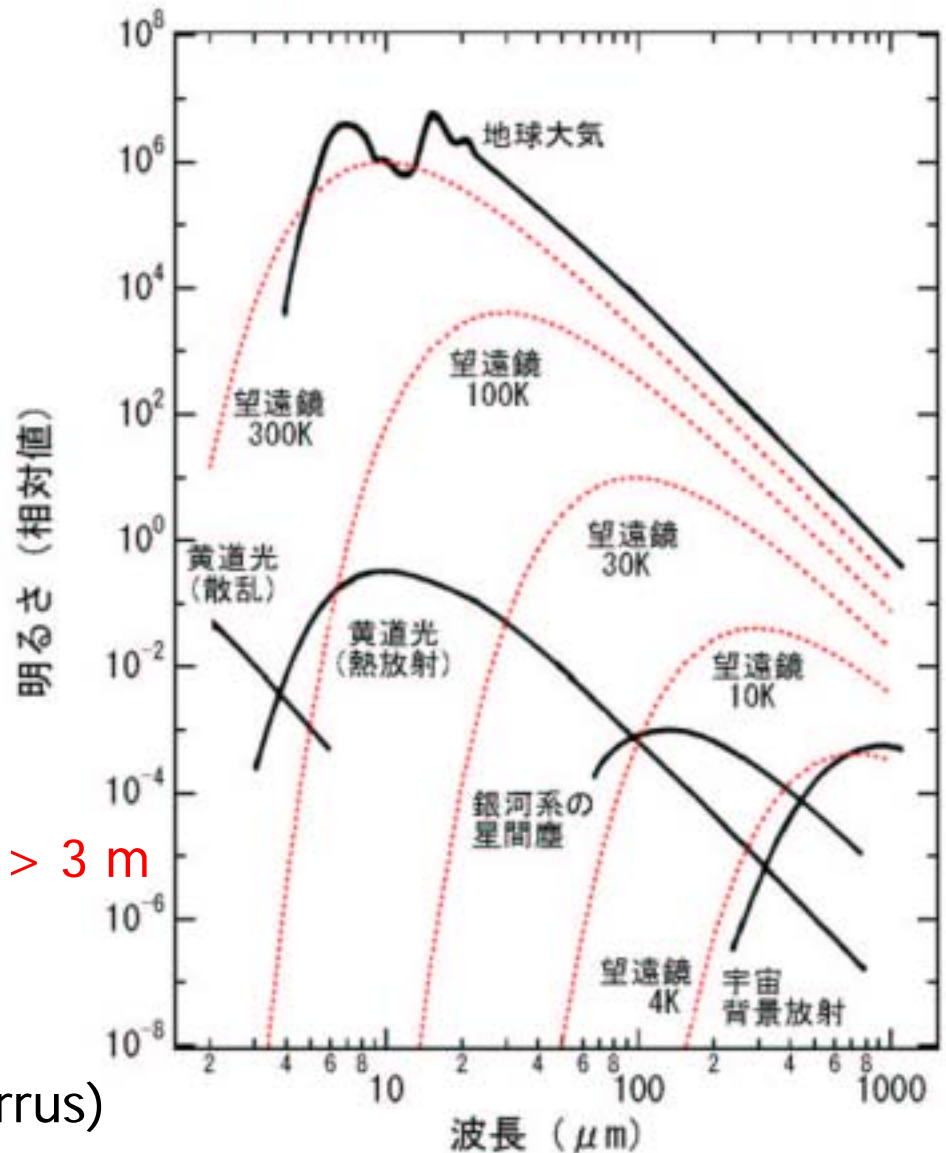




Requirements for SPICA

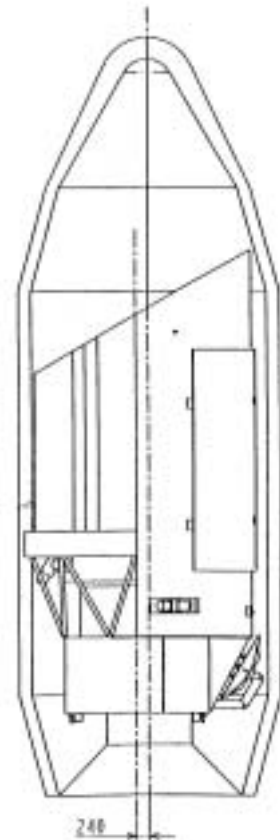
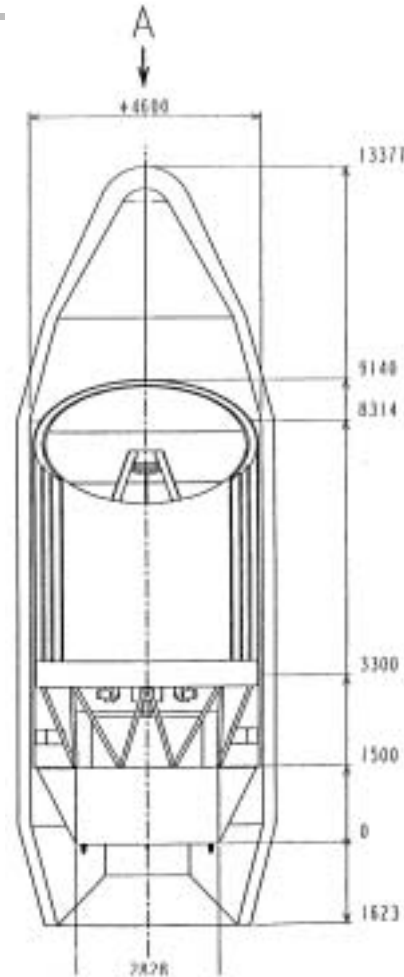
Requirements for Telescope

- Cooled Telescope
 - Natural BG Limited
 - $T < 5K$
- Large Aperture
 - High Spatial Resolution
 - $\Delta \theta = \lambda / D$
 - $40AU @ 10pc, 50 \mu m \rightarrow D > 3 m$
 - Good Sensitivity
 - Collect. Area $\propto D^2$
 - Confusion ($\sigma \propto D^{-2.5}$ for cirrus)
 - $2mJy @ 100 \mu m \rightarrow D > 3 m$



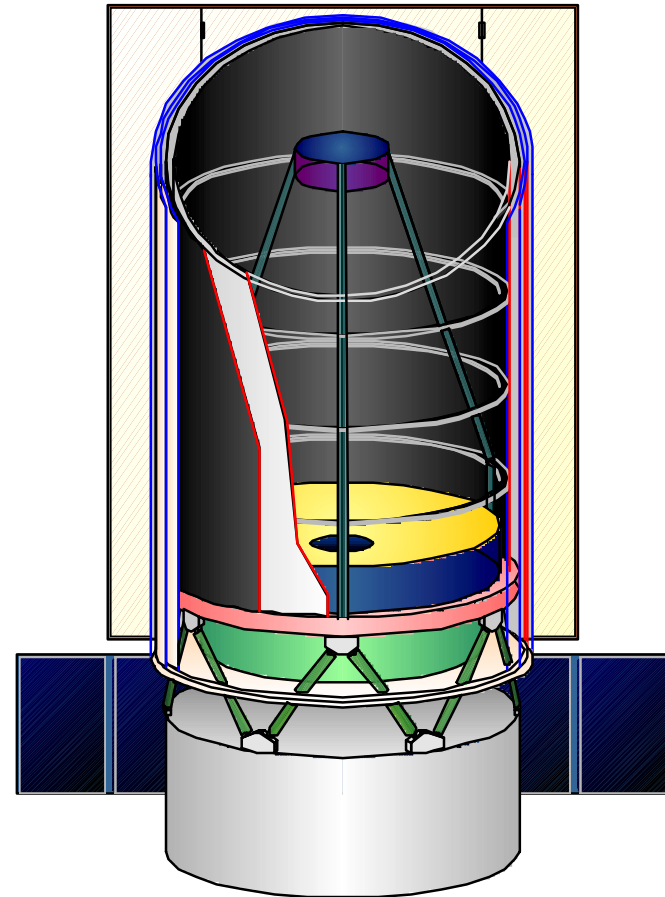
Telescope Size

- The larger, the better,
 - but....
- Feasible Size: $D = 3.5$ m
 - Monolithic (not deployable) mirror
 - Much larger than those of previous missions ($D < 1\text{m}$)
 - Simple System
 - High feasibility
 - Smooth PSF



Outline of SPICA

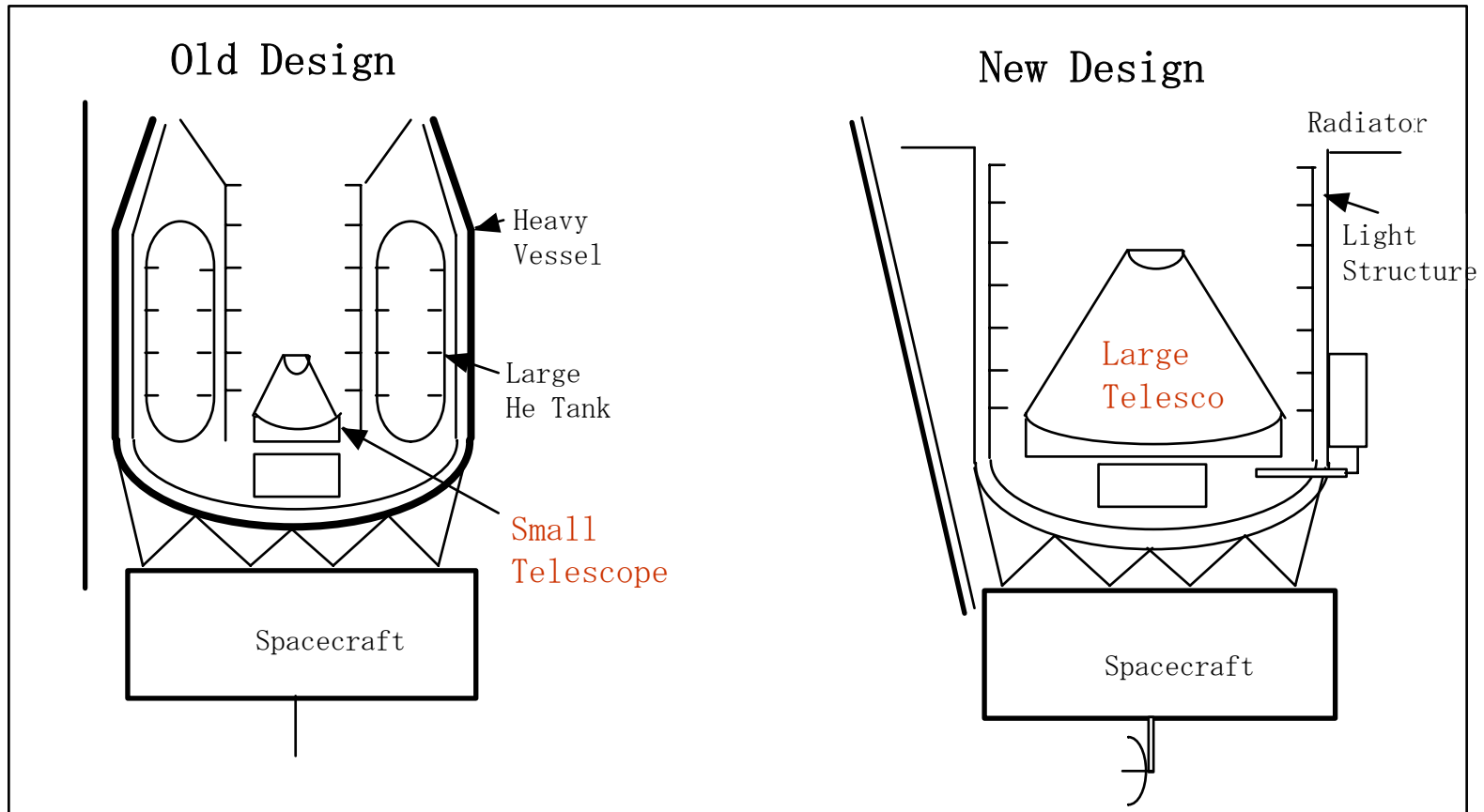
- To reveal the history of Universe through Infrared Observations
- Telescope: **3.5m, 4.5 K**
 - HSO: 3.5m, 80K
 - JWST: ~6m, <50K
- Core λ : 5-200 μ m
- Orbit: Sun-Earth L2 Halo
- Warm Launch, Cooling in Orbit
 - No Cryogen
- Launch: ~2010





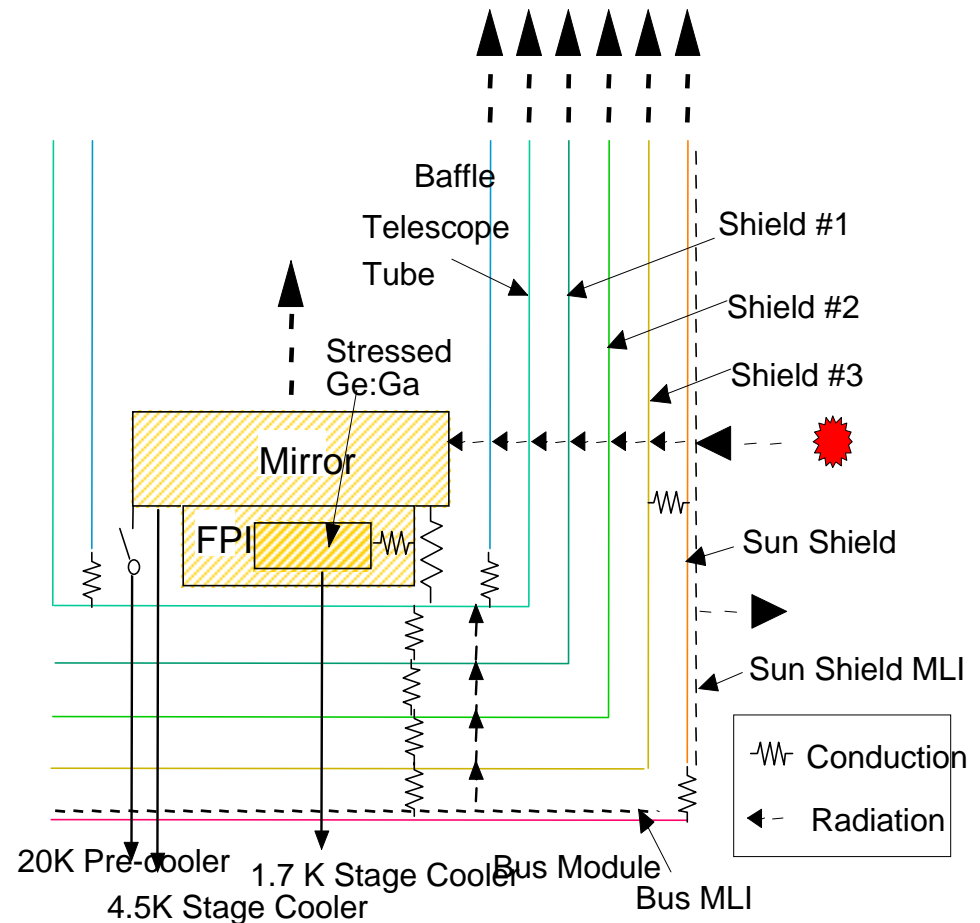
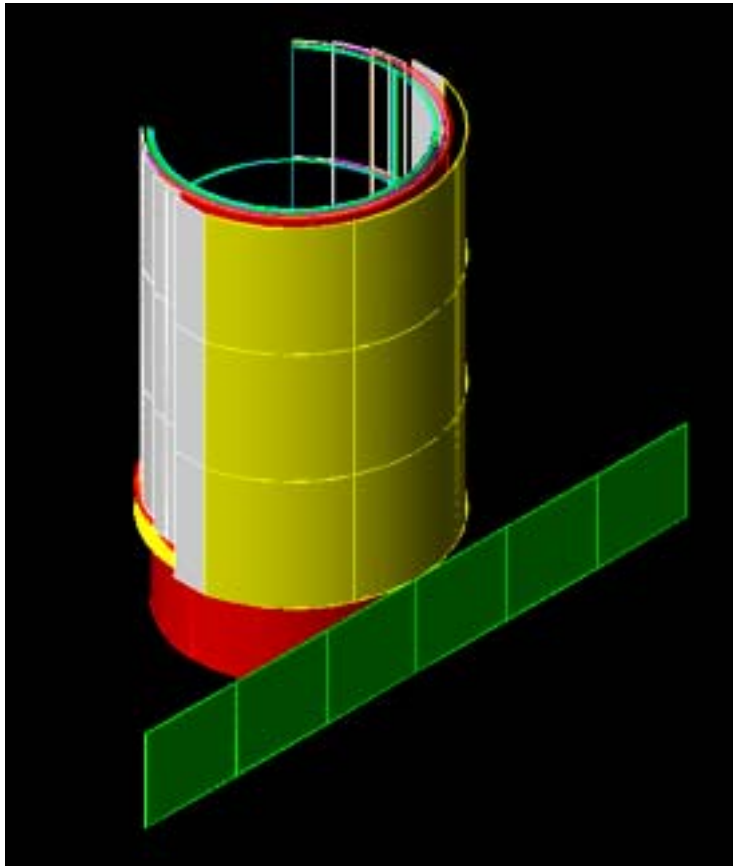
Thermal Design of SPICA

Revolution of Design Philosophy



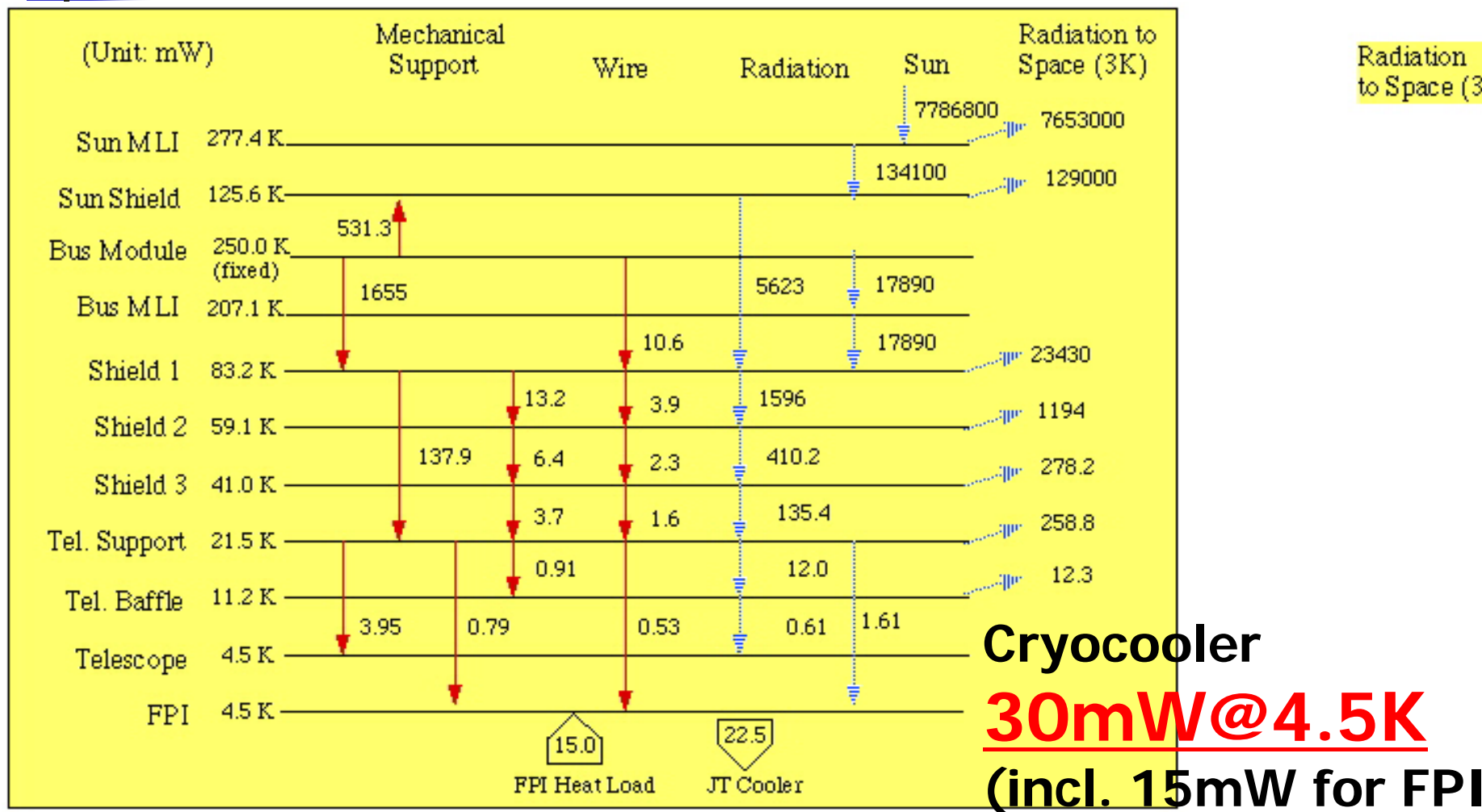
No Cryogen → Large Telescope

Effective Radiative Cooling + α



3K Space is not cold enough -> Additional Cooling

Heat Flow





Capability of SPICA



Focal Plane Instruments

- First Priority
 - Mid-Infrared Camera & Spectrometer
 - 0.3'' @ 5 μ m
 - with Coronagraphic Capability
 - Far-Infrared Camera & Spectrometer
 - 3.5'' @ 50 μ m
 - Availability of Large-format Arrays
- Second Priority
 - NIR Camera & Spectrometer
 - Sub-mm Camera & Spectrometer

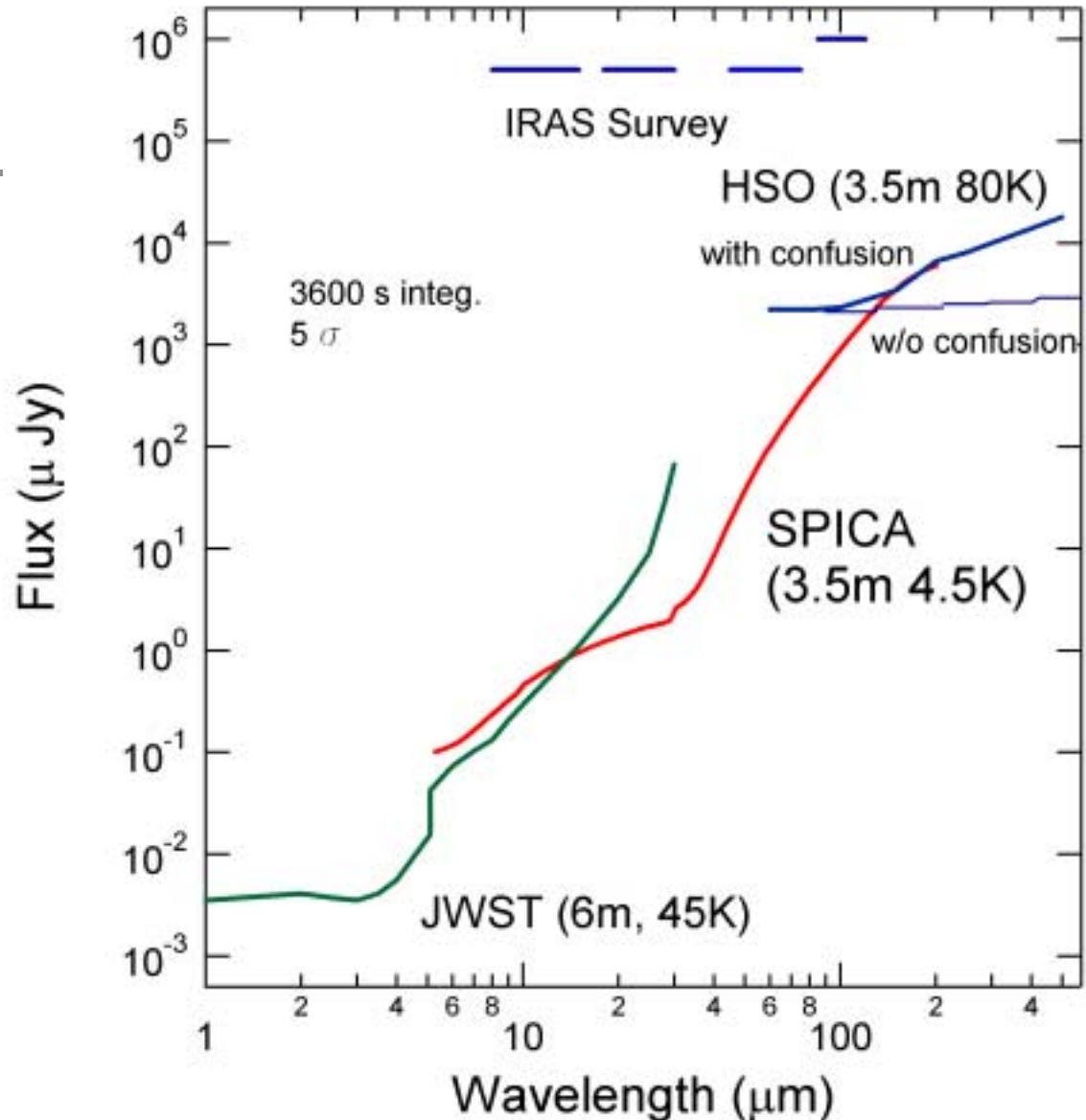
SPICA

Sensitivity

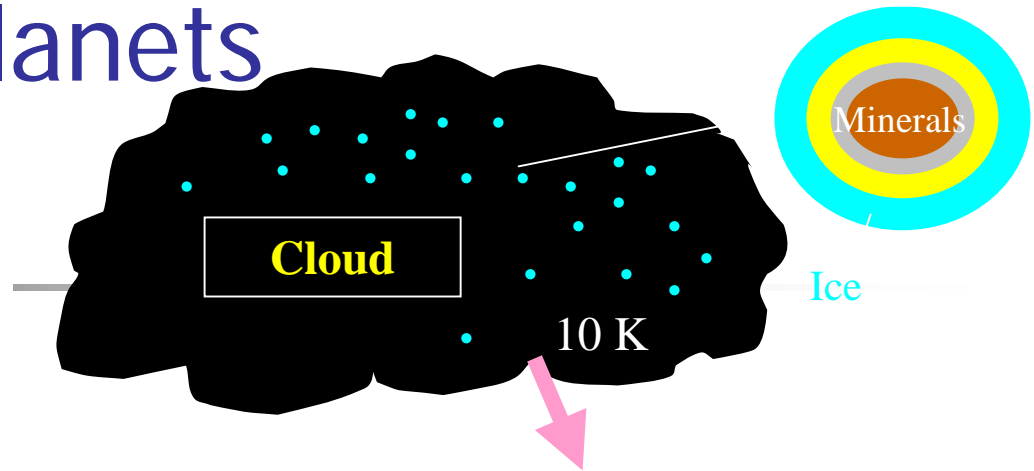
- Optimized for Mid- & Far-Infrared

- Most Sensitive among proposed missions @ 15-130 μm

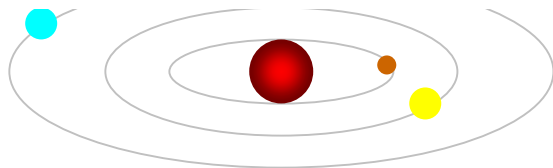
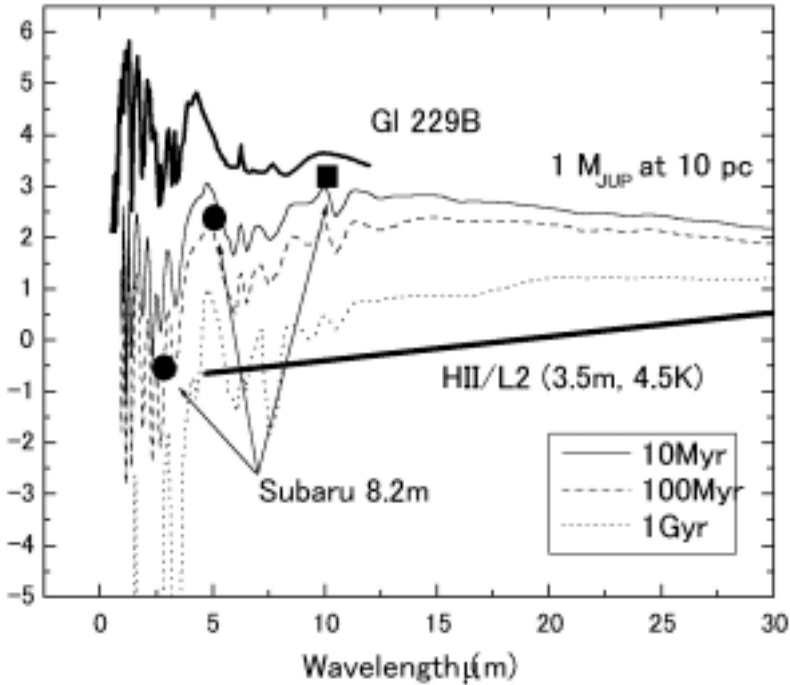
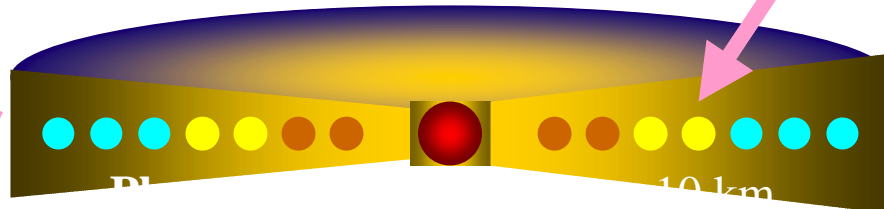
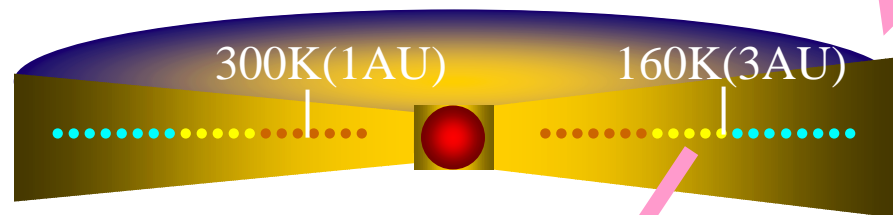
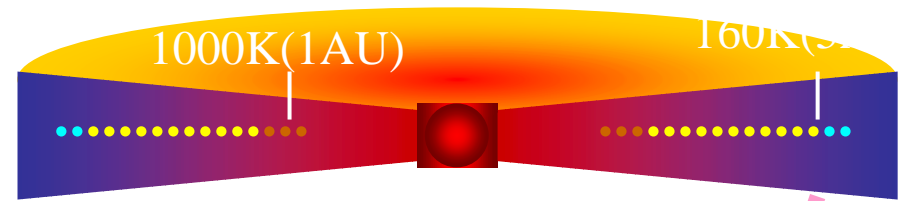
- Complimentary to HSO & JWST



From Disks to Planets

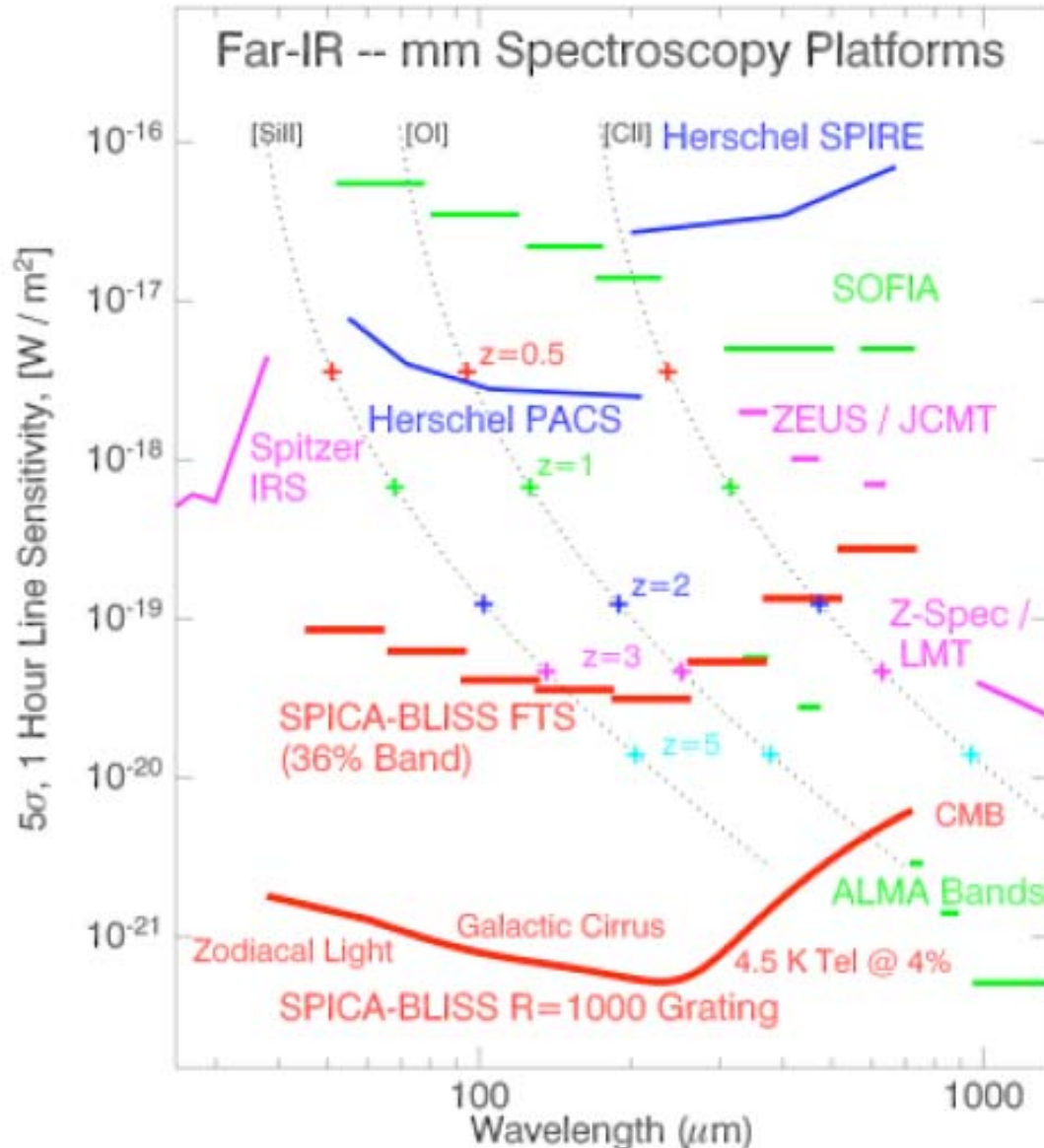


Protoplanetary Disk



Planetary Systems and Exozodi

Sensitivity Gain for Spectroscopy



- Huge Gain over Warm Telescopes
 - Beats confusion
- Fine Structure Lines can be detected up to $Z \sim 5$



R & D Program for SPICA



Technical Issues

- Cryogenic System
 - Especially Mechanical Cryocoolers
- Light-Weight, Cryogenic Telescope
- Detectors
 - Large-Format
 - Very low NEP
- Spacecraft System
 - Fine Attitude Control
 - Thermal control



Cryocoolers: Requirements

- Stirling Cooler
 - Pre-cooler
 - 200mW @ 20K
- JT Cooler (1)
 - To cool telescope and MIR instrument
 - 30 mW @ 4.5 K
- JT Cooler (2)
 - To cool FIR detectors
 - 10 mW @ 1.7 K

Stirling Cooler



ASTRO-F

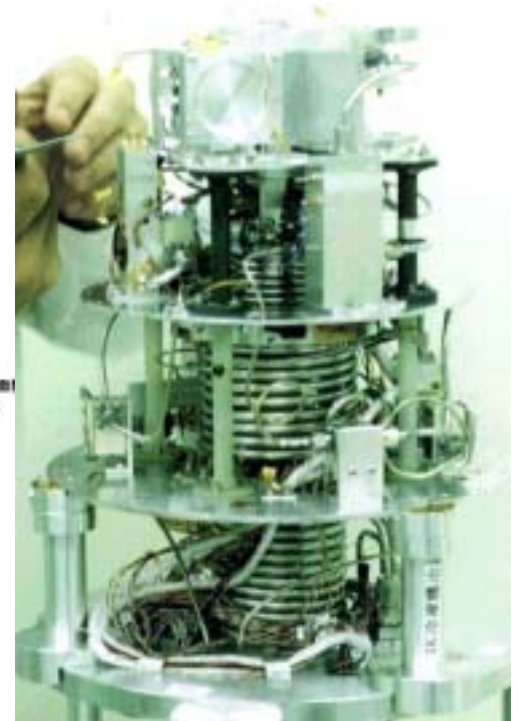
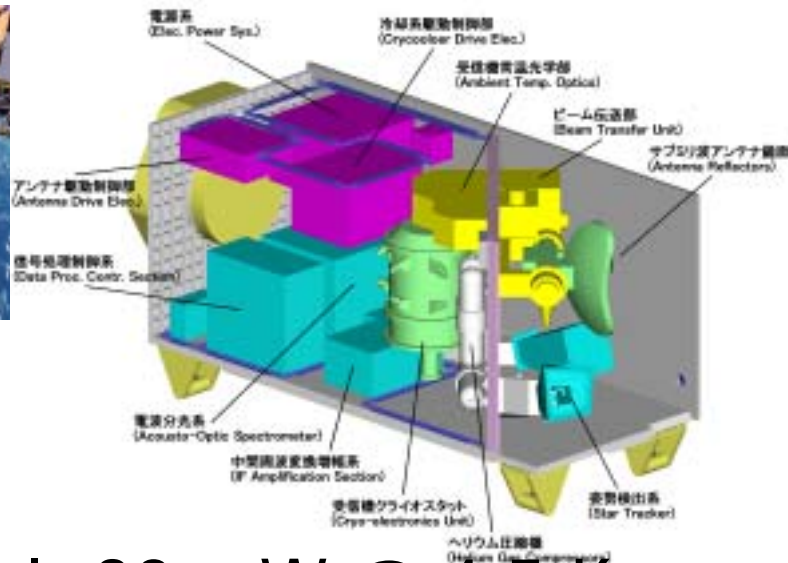


- Goal: 200 mW @ 20 K → Ok !
- Working for more than 3.5 years !
- To be flight-proven in 2005 (ASTRO-F)
 - Also ASTRO-E2, Selene, NeXT, VSOP-2

JT Cooler (1)

Developed for **SMILES**

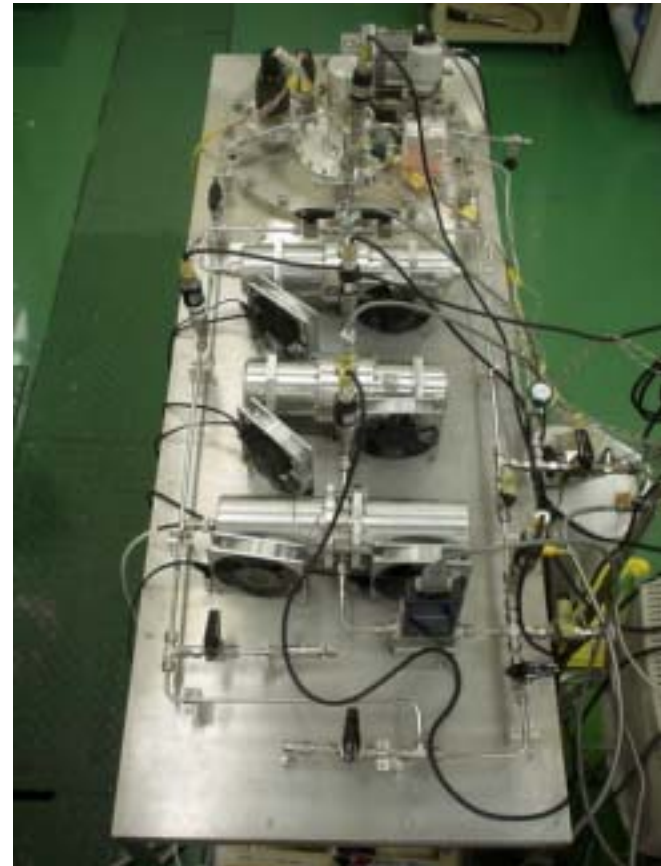
*(Superconducting Submillimeter-wave
Limb-emission Sounder)*



- Goal: 30 mW @ 4.5 K → OK !
- Working for more than 8,000 hours !
- To be flight-proven in 2006

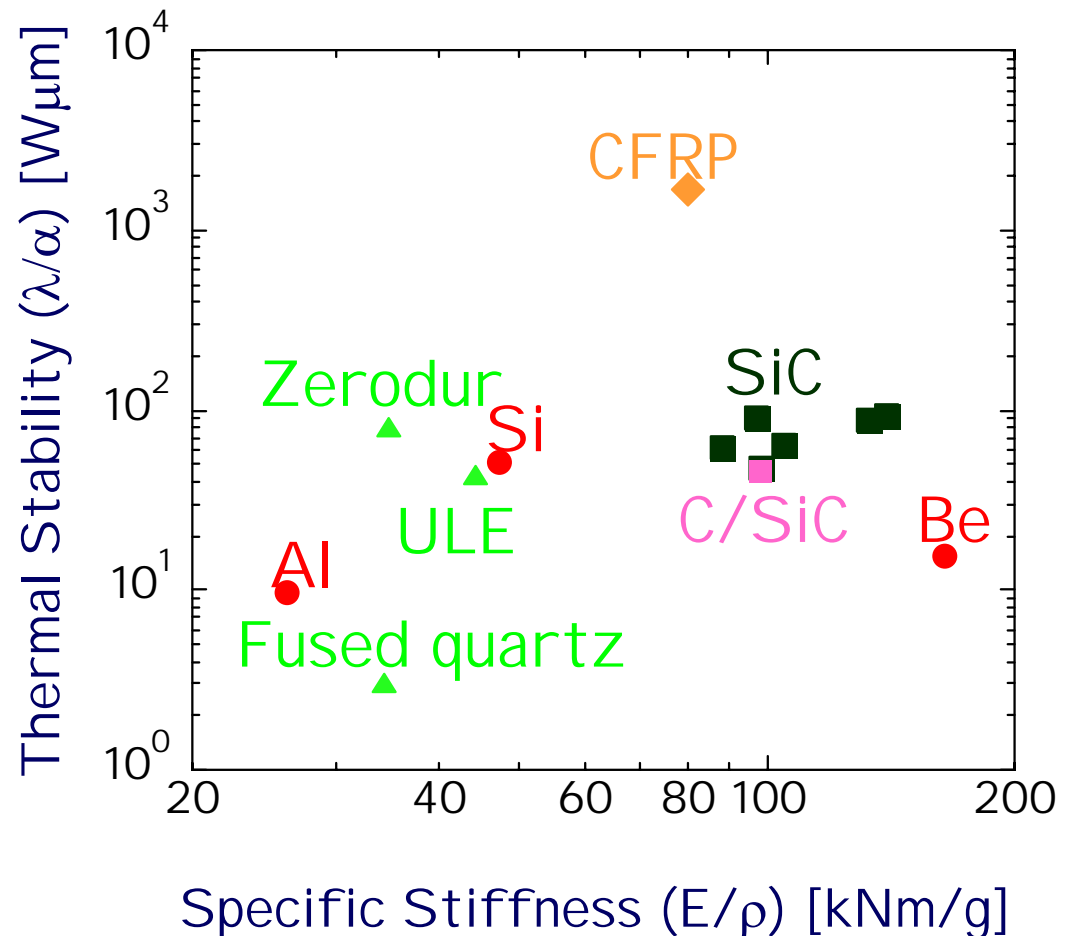
JT Cooler (2): 1K-class cooler

- Goal: 10 mW @ 1.7 K
- ^3He for Low Temp.
- Working! 12mW@1.7K



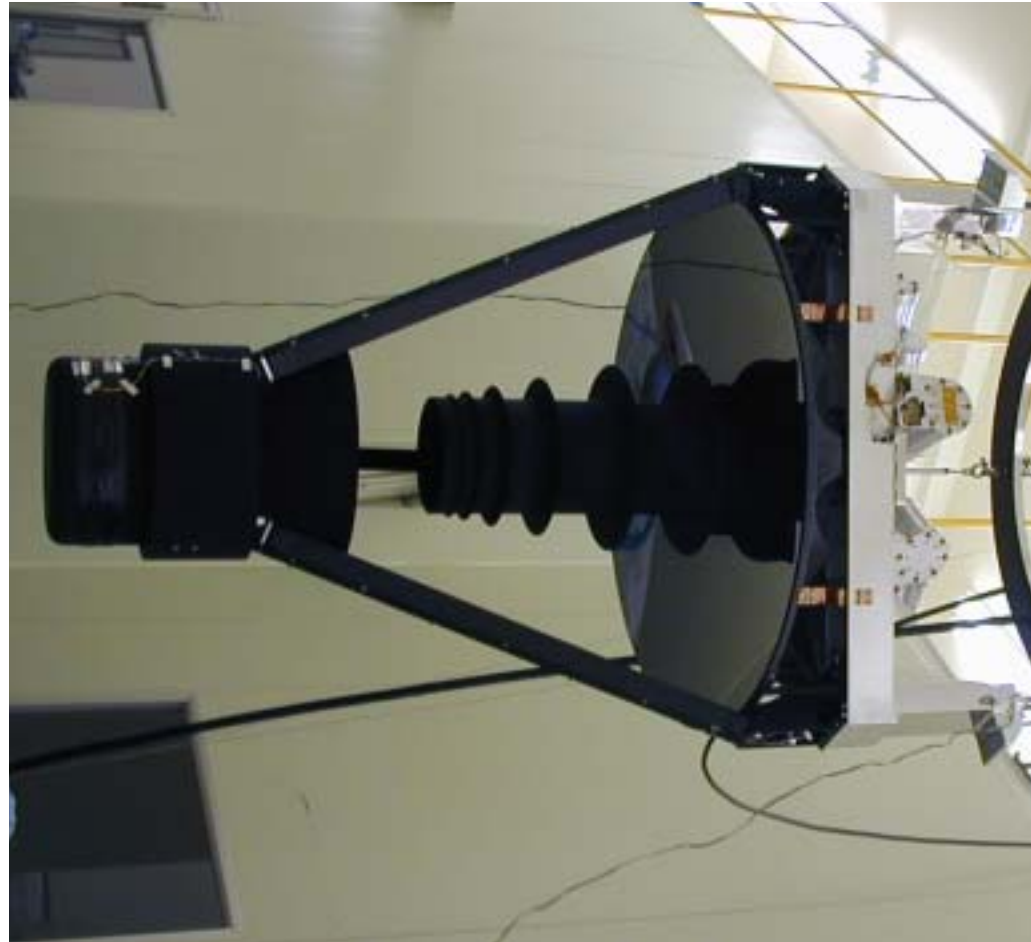
Telescope: Requirements

- Diffraction Limit at $\lambda > 5 \mu\text{m}$
- Operat. Temp. 4.5 K
- Light-Weight: 700 kg as a system
- Choice of Material



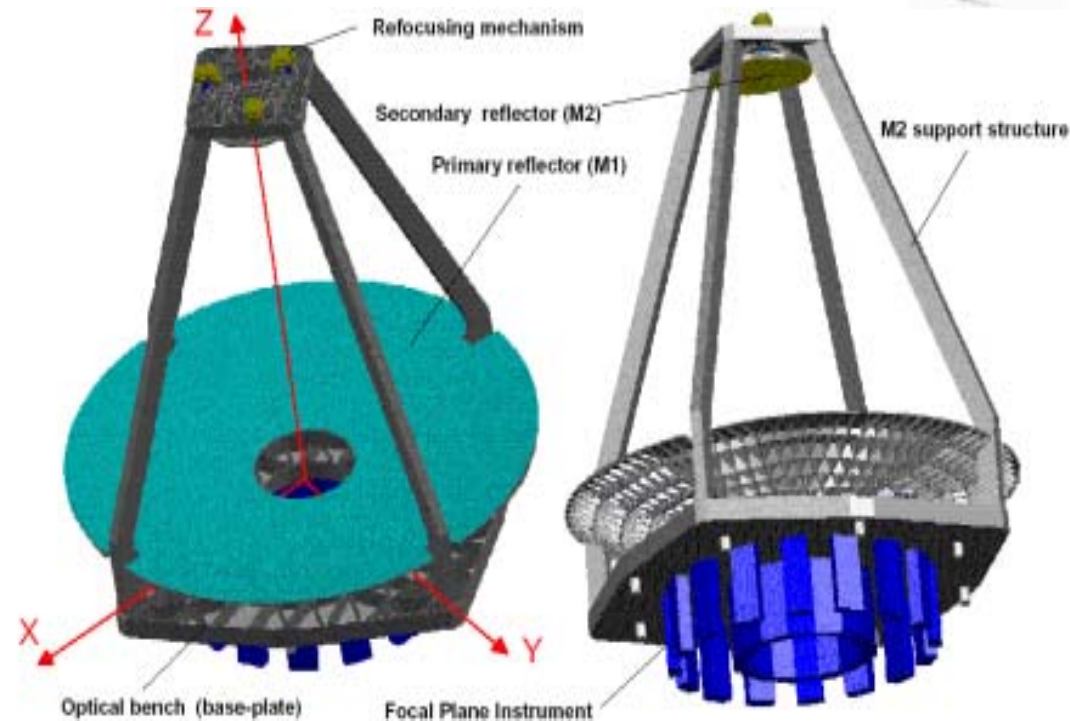
ASTRO-F Heritage

- 68.5 cm R.C.
- 5.8 K
- Diff. Limit @5 μ m
 - tested @ 10K
- SiC
 - Light (1 1 k g)
 - Porous Core
 - CVD Coat
 - Not applicable for 3.5 m telescope



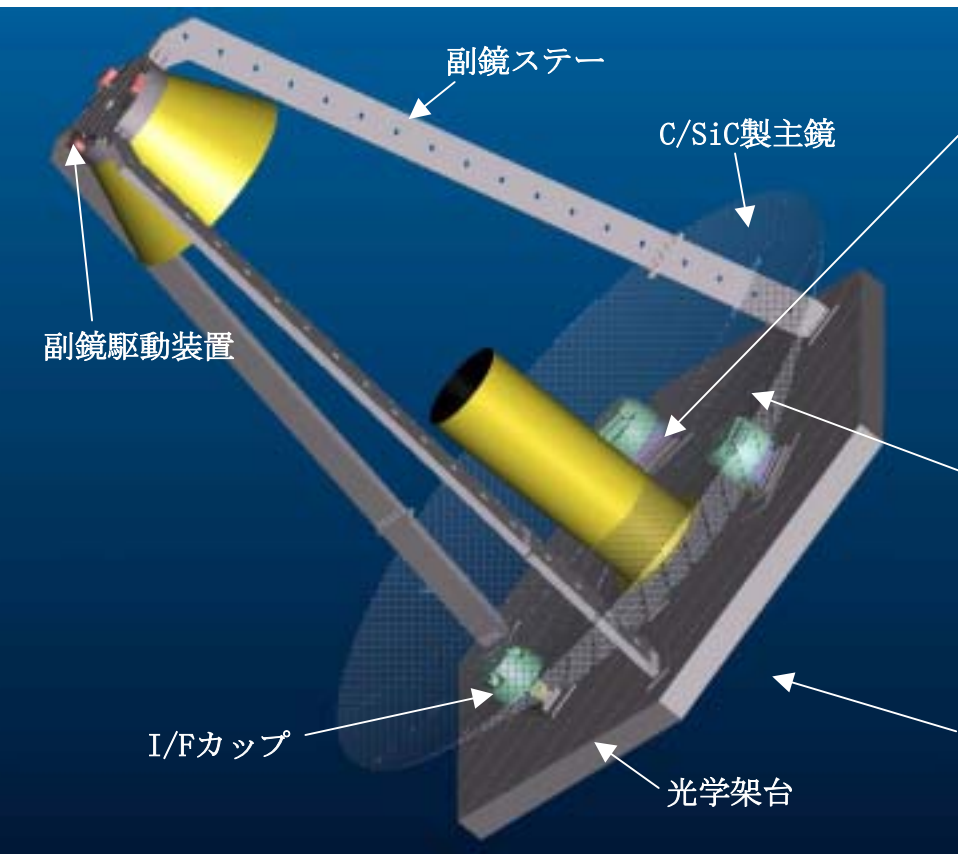
SPICA Telescope Candidate (1)

(Sintered SiC: Herschel Technology)



- Passive Support is OK for SPICA
- Simple system

SPICA Telescope Candidate (2)



- Rigid Mirror with C/SiC Composite
 - High Toughness
- Fixed Support System with small Distortion
 - Passive Support
- Active Actuators (Optional)

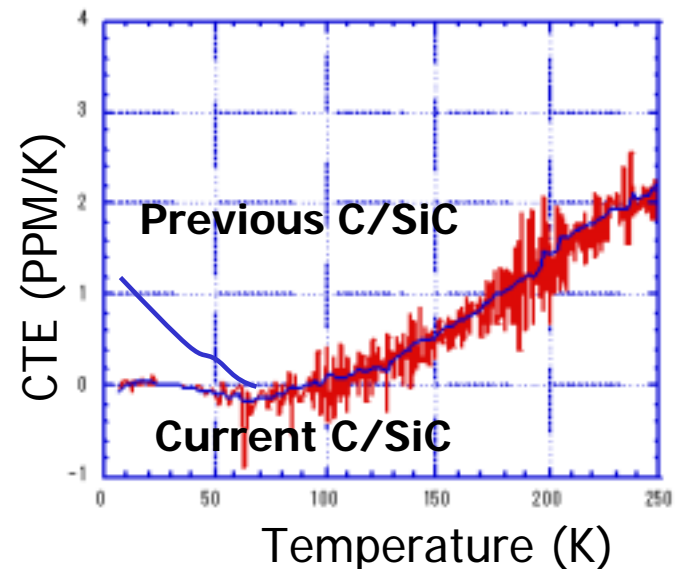
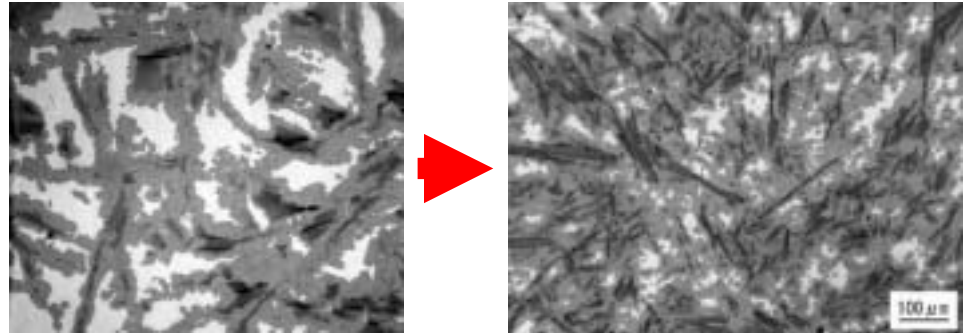
New Material: C/SiC Composite

■ Advantage

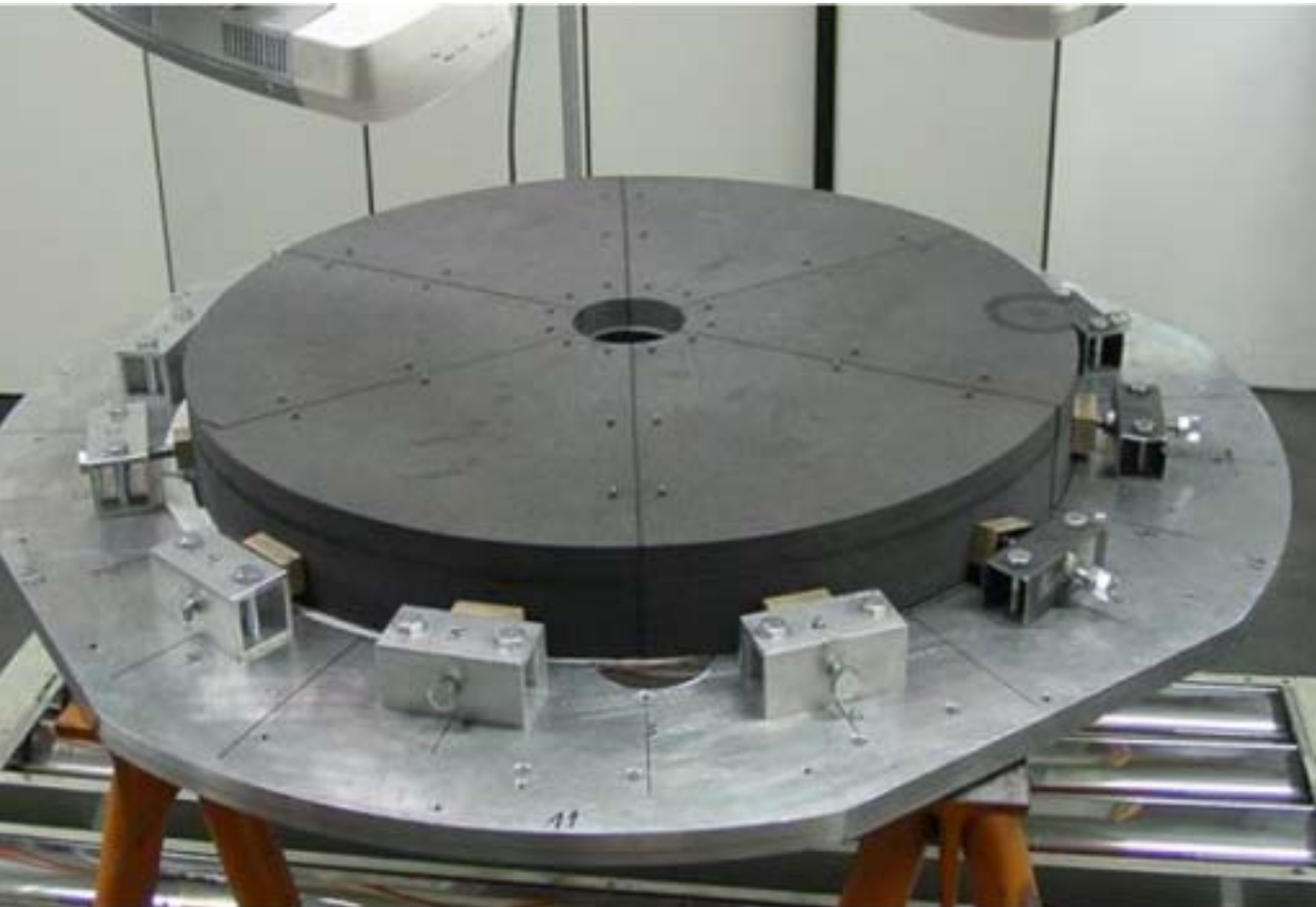
- Composite Material
 - Controllable Properties
 - High Damage Tolerance
- Large, monolithic Mirror

■ Improvements

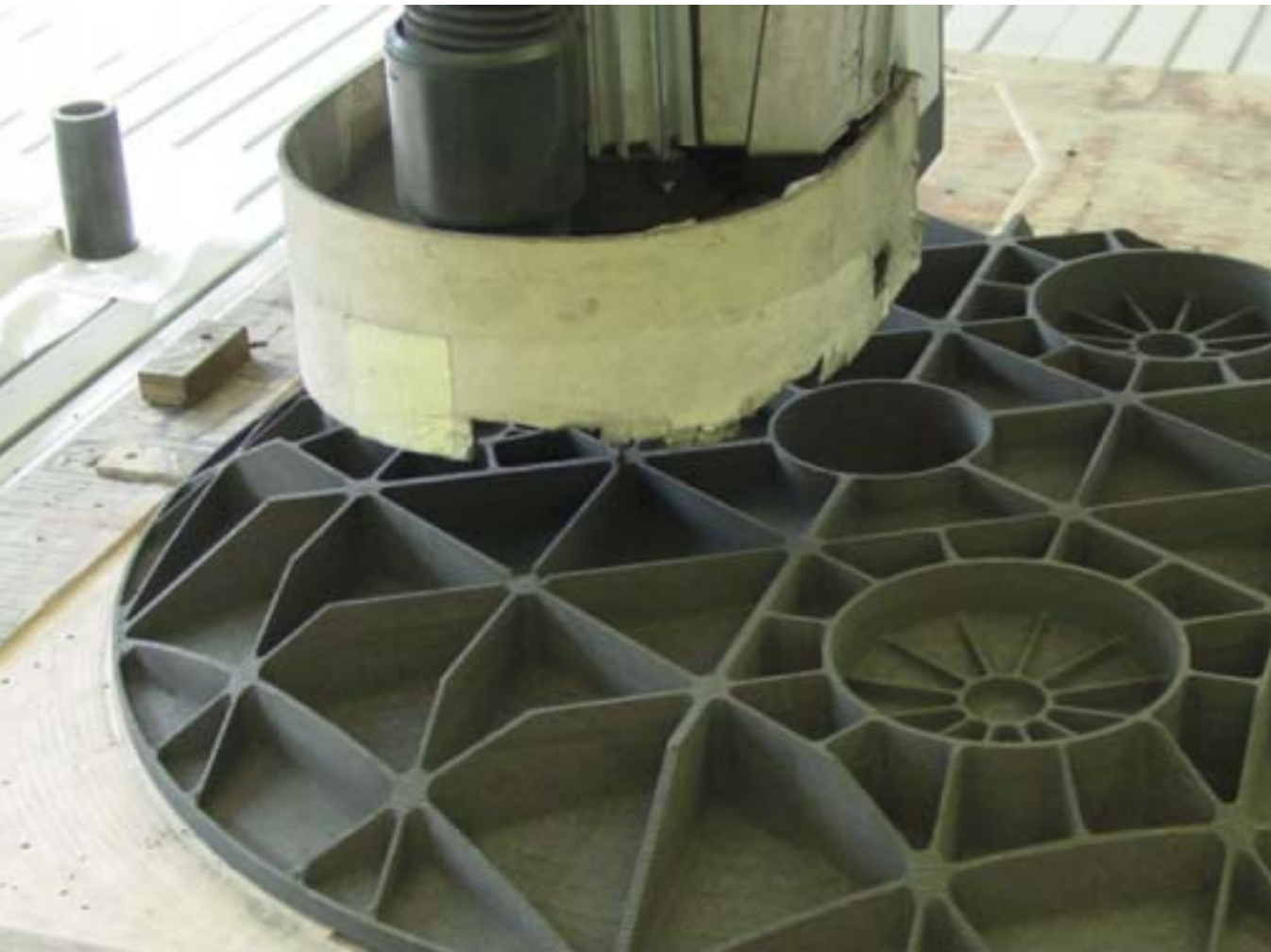
- Large CTE at Low-T ?
 - Improved
- Small Specific Stiffness ?
 - Improved
 - $E/\rho \sim 120 \text{ GPa g}^{-1} \text{ cm}^3$
- Surface Roughness ?
 - Improved ($<20 \text{ nm rms}$)



BBM: 70cm C/SiC Mirror



BBM: 70cm C/SiC Mirror

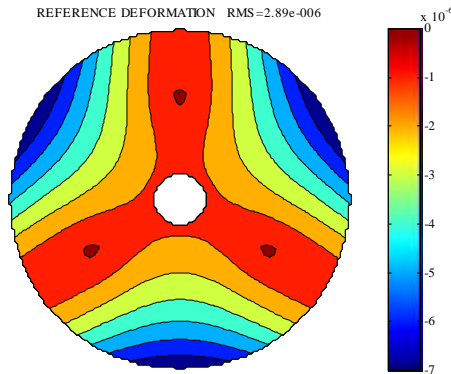
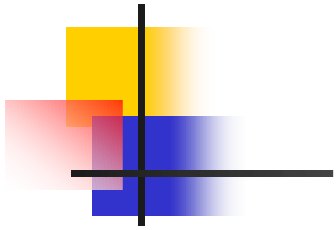


BBM: 70cm C/SiC Mirror



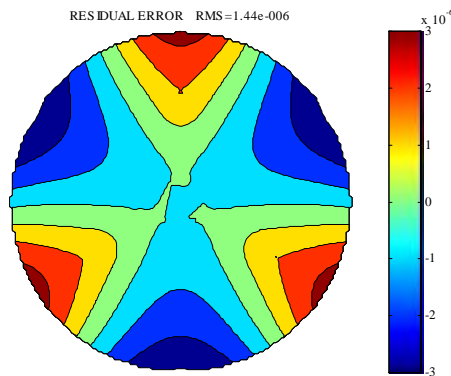
- Grinding Finished
- Now being Polished
- Optical Performance test at Liq. He Temp. is Scheduled

Active Actuators (Optional)

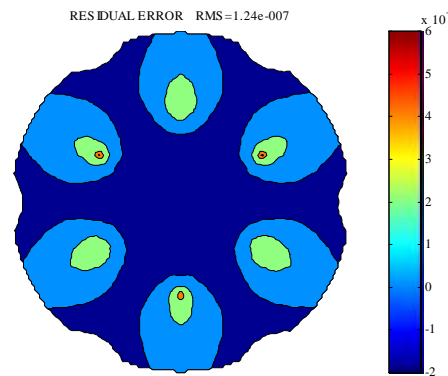


Three-Actuator system is effective for low-order Error

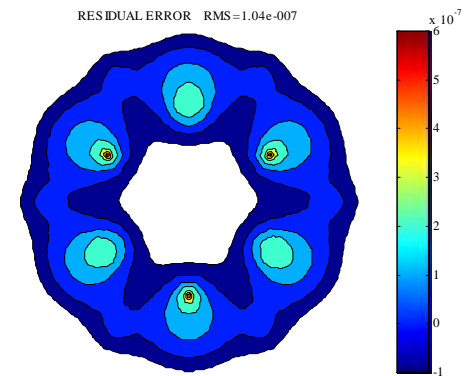
Errors to be corrected



Errors after 2nd Mirror Correction (piston, tilt, focus)



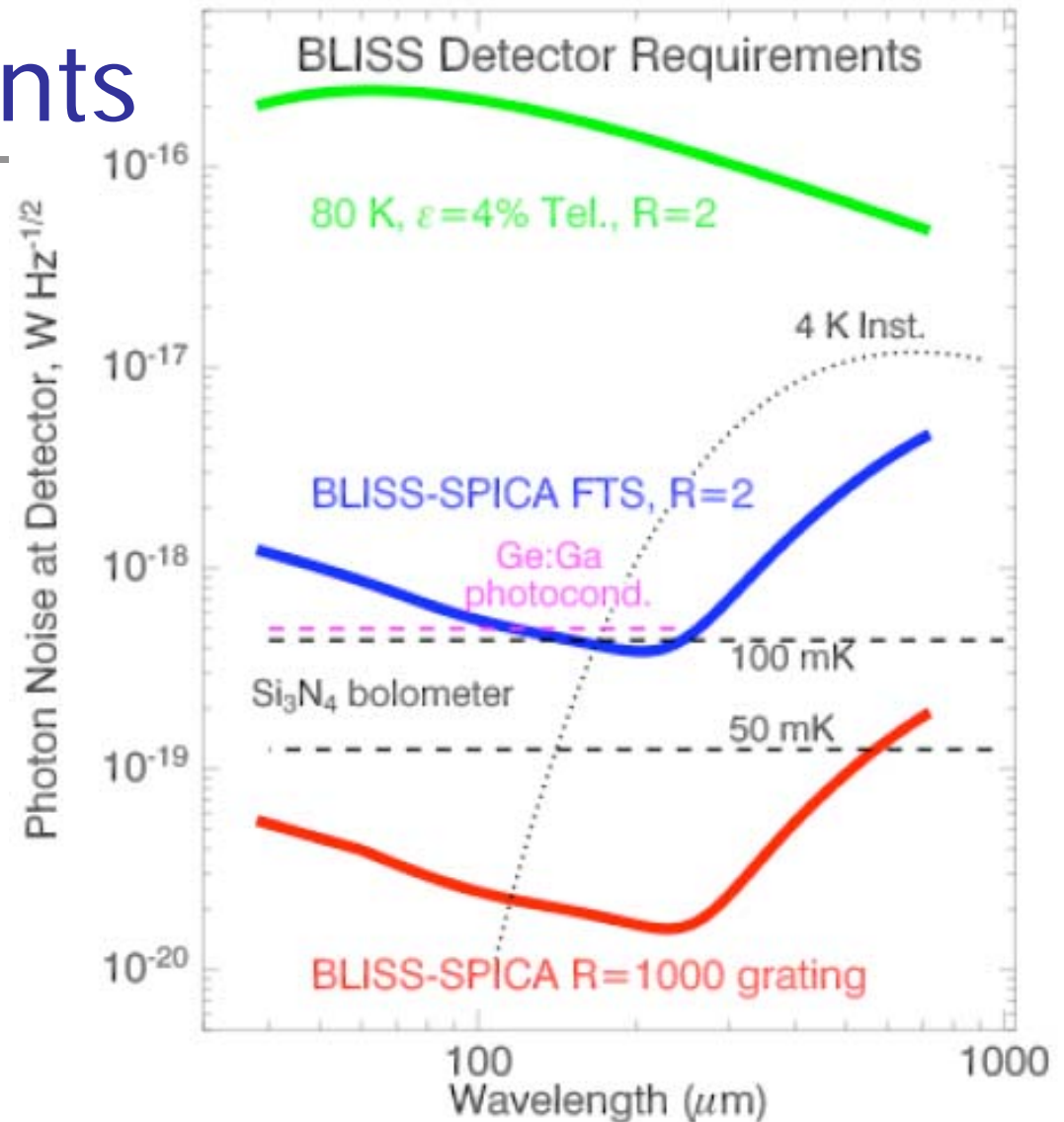
Errors after the correction by 2nd Mirror and **3 Actuators**



Errors after the correction by 2nd Mirror and **9 Actuators**

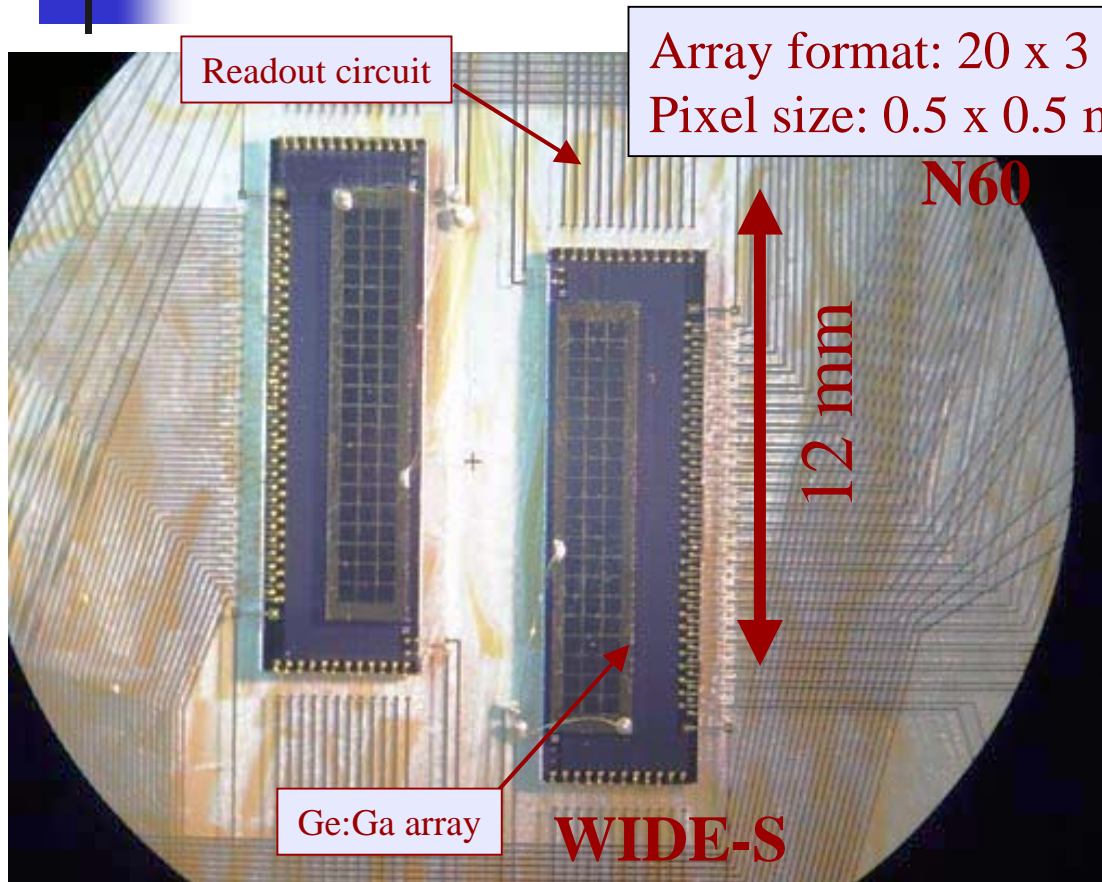
Detectors: Requirements

- Good Sensitivity
- Large-Format



Large-format FIR Detector

Ge:Ga Monolithic array.



Direct In-Bump of
Detectors on Read-
out Electronics

Key Technology for
Large-format Array



Current Status and Schedule



Current Status

- Compiling Proposal for JAXA
 - To put SPICA on Japanese Strategic Plan of Space Science
 - Scientific Objectives, Mission Description, Detailed Design Study
- Submitted two proposals for NASA
 - To put SPICA on NASA's strategic plan
 - Background-Limited Infrared –Submm Spectrograph: BLISS (P.I. M. Bradford)
 - Survey of Infrared Cosmic Evolution: SIRCE (P.I. H. Moseley)
- Funding after the launch of ASTRO-F ?

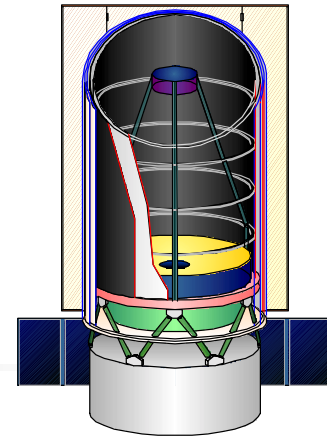


Other International Collaboration

- Korea
 - Successful collaboration on ASTRO-F Data reduction
 - Successful Launch of FIMS (FUV Imaging Spectrograph) on STSAT-1 in 2003
 - Very much interested in Collaboration of Hardware
- Also interest from
 - Europe, Taiwan, ...

SPICA

A Unique Opportunity



- Huge Jump from Previous Missions
 - 3.5 m cooled telescope
 - Previous cooled telescopes < 1m
- Uniqueness
 - Optimized for MIR & FIR
 - Complementary with other Missions
- High Feasibility
 - On the basis of technologies available now (or to be available soon)
- Precursor for the Next Step
 - SAFIR, SPECS, ...



SPICA

Space Odyssey ~2010